A PRIMER

URBAN SOIL CONTAMINANTS AND REMEDIATION

Resurgence of interest in urban farms and gardens raises questions about soil contamination, especially lead. This primer provides a basic understanding of the problem, and the solutions available via compost utilization.

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GROWING food crops in backyards and pea patches in cities used to be commonplace. Victory Gardens in World War II supplied up to 40 percent of the produce consumed in the U.S. Now, for a variety of reasons, there is a resurgence of interest in growing food. Home grown or locally grown generally means better nutrition, lower transport costs, and a lower carbon footprint. It also helps people reconnect with the process of how things grow and where food comes from, teaches kids about their environment and provides significant savings on grocery bills.

However, things have changed since WW II. Our understanding of how things grow and what constitutes a healthy soil are in many ways less sophisticated than they were 70 years ago. In addition, we have done a fair bit of damage to our urban soils since WWII. Most urban soils have elevated concentrations of a range of contaminants including lead and PAHs (poly aromatic hydrocarbons). Soils have also been built on, parked on, and largely ignored. In order to have this resurgence in urban agriculture grow and flourish, it is important to disseminate information on the unique characteristics of urban soils and how to work with them.

People who have just discovered the seed section in their local hardware store will have to confront two sets of obstacles — contaminants and poor soil — before they can successfully create their own urban jungle. Conquering these two problems requires two sets of skills. For contaminants, the basic tool required to garden is knowledge. Just because a contaminant can be measured, does that mean there is a danger associated with eating food grown in that soil?

For poor soil, a different and more fundamental type of knowledge is required. Here, a basic understanding of how soils function and knowledge of what inputs can improve that function is key. For the urban gardener, it just so happens that improving soil function can lead to both reduced contaminant concentration and potentially reduced bioavailability of the contaminants.

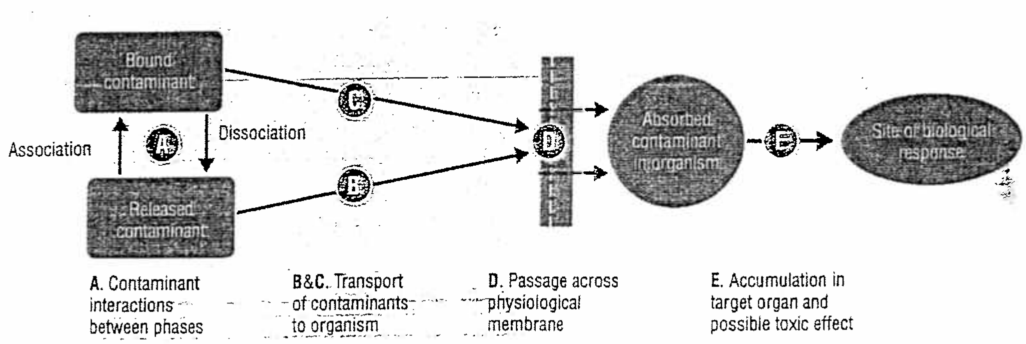
PRIMER ON CONTAMINANTS

For urban soils, a contaminant can be considered a compound that is present in soils at higher concentrations than would be expected, and that has a potential to cause harm as a result of these elevated concentrations. For example, cadmium can be detected in all soils, generally at concentrations less than 1 part per million. A contaminated soil would have cadmium concentrations above the level that is normal for that area. To decide if this elevated cadmium is something to be concerned about, it is critical to realize that the potential for a contaminant to cause harm is related to several factors:

- How high the concentration is in soils;
- What are the different ways (pathways) that the contaminant can cause harm to those exposed to the soil;
- Frequency of exposure to the contaminant by each of the different pathways.

These questions form the basis of an understanding of bioavailability. The bioavailability of a contaminant is a measure of the portion of the total contaminant that has the potential to harm a living thing. The bioavailable concentration of a particular contaminant will vary based on the route of exposure and the end receptor. Figure 1 is a diagram used to explain the bioavailability concept in a National Academy of Science

Figure 1. Bioavailability processes in soil or sediment



SOURCE: National Research Council

study on the Bioavailability of Contaminants in Soils and Sediments (2002).

For urban soils, the most ubiquitous contaminant is lead. The question is: Is eating food grown on lead contaminated soil a concern? Luckily, a lot of prior research has been done to understand the hazards posed by elevated soil lead.

SOIL LEAD

According to the U.S. Centers for Disease Control and Prevention, lead poisoning is the most common and serious environmental disease affecting young children. This is particularly a problem for young children living in urban areas (Ryan et al., 2004).

Current sources of lead in the environment are the remnants of a long history of lead use. Lead was added to gasoline as an antiknock agent. Lead paint was another source of lead in the environment. Although both of these uses of lead were banned over 40 years ago, elevated lead in urban environments is a reminder of our history of widespread use of lead.

Urban areas, particularly neighborhoods with older homes and busy streets, are centers for lead contamination. Lead is very insoluble in soils and will stay in the soil surface. As a heavy metal, lead will accumulate in soils. Median concentrations of lead in inner city soils are greater than 1,000 ppm.

Elevated soil lead is a problem for young children. Children are more at risk than adults from elevated soil lead because they are still growing and will absorb lead more easily than adults. The primary exposure pathways for soil lead are direct ingestion of soil and inhalation of lead contaminated soil particles. Little children play outside and will deliberately (pica behavior) or inadvertently eat soil. When they eat dirt they will be exposed to the lead in the soil. A healthy plant cover on lead contaminated soil will reduce the potential for dispersal through wind of the soil. It will also make it more difficult for a child to find dirt to play in.

If a child eats soil on an empty stomach, an empty stomach is very acidic and the lead in the soil will become soluble and can be absorbed into the body. Conversely, the soil is never acid enough to make lead soluble. Plants don't need lead to grow. Plant concentrations of lead, even in severely contaminated sites, while above detection, are generally in the very low ppm range. Eating vegetables grown in lead-contaminated soil is generally not a concern. As our ability to measure concentrations of lead becomes more sophisticated, we are able to detect lead concentrations in plants in the parts per billion range.

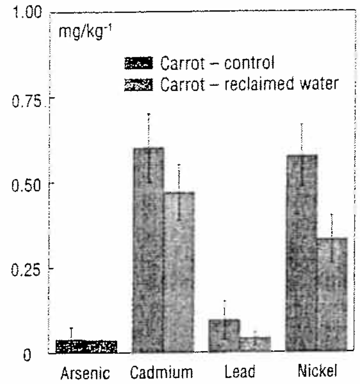
Figure 2 shows lead, arsenic, cadmium and nickel concentrations in carrots grown in a greenhouse study using soils from a truck farm garden irrigated with tap water and reclaimed water from a wastewater treatment plant. Lead in carrots was above detection limits. However, this is not a reason to avoid eating carrots. The potential for the lead in the carrots to cause harm is limited by two factors: 1) Lead in the carrots will not be readily absorbed into your body as your stomach pH when you are eating becomes less acid, reducing the solubility of the lead; and 2) The portion of your diet from the carrots and other vegetables from a home garden is likely to be low in comparison to the portion from agricultural soils where plant lead and other contaminant concentrations are likely to be even lower.

The primary danger with elevated lead in urban soils is for children who eat soils. Children are both more likely to eat soils than adults and are more efficient at absorbing any lead that may be in the soil. A thick thatch of grass will reduce the potential for children to have contact with lead contaminated soils.

The standard way to fix lead-contaminated soils is to remove the soil and replace it with clean soil. This is very expensive. It is difficult to find a disposal site for contaminated soils and also difficult to source clean topsoil. The only sites where this type of remedy has been used are the most severely contaminated sites where industrial activities are the cause of contamination. Sites on the USEPA National Priorities List (Superfund sites) have used removal and replacement of contaminated soils as a way to clean up contamination.

In inner cities where soil lead is often higher than on Superfund sites, there is no source of funding to clean up soils. In some cases volunteer organizations provide educational guides to reducing the risks posed by excess lead in soils. The Kennedy Krieger Institute is an example of an organization that offers educational materials on soil lead (www.kennedykrieger.org/kki_diag.jsp?pid=1090). These guides often recommend things like washing your hands before you eat and keeping a clean house. In other cases, nothing is done to reduce the danger posed by excess soil lead. However, selecting tools to make plants grow better will also work to reduce hazards posed by elevated soil lead concentrations.

Figure 2. Greenhouse study growing carrots in soils irrigated with tap water (Control) and reclaimed water (RW) from wastewater treatment plant



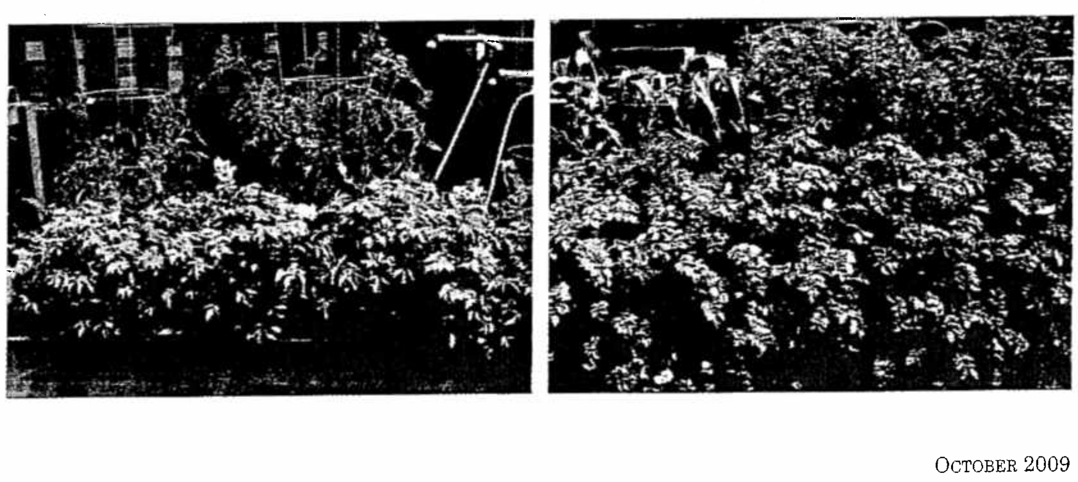


Figure 3. Vegetables grown in a commercial topsoil blend (left) versus commercial topsoil blend mixed with 50 percent biosolids compost (right)

COMPOST FOR URBAN GARDENS

Because compost provides both fertility and organic matter to soils, plants grown with composts tend to be bigger and greener than plants grown in poor soils. Urban soils tend to be highly compacted and low in nutrients. Adding composts to urban soils will generally increase plant growth. Vegetables grown in a commercial topsoil blend versus a commercial topsoil blend mixed with 50 percent biosolids compost are shown in Figures 3a and 3b, respectively.

Adding composts to soil will also reduce the lead concentration in the soil, thereby reducing hazards posed by soil lead. Although composts will have measurable concentrations of lead, these will be much lower than the soil and will dilute the soil. Metal concentrations for two different composts are listed in Table 1. One is made from yard waste and food scraps. The other is made from biosolids and sawdust.

Compost was added to a lead contaminated orchard soil in a field study to test the ability of the compost to reduce the availability of soil lead. Lead arsenate pesticides were routinely used in orchard soils in the early part of the 20th century. The change in total soil lead concentration after addition of 10 percent by weight biosolids compost is shown in Figure 4.

If the top 3-inches of a lead-contaminated soil is mixed 1:1 with biosolids compost, the lead concentration in the soil will be diluted by approximately half.

In addition to dilution, studies have also shown that some biosolids composts, primarily those high in iron, can reduce the availability of soil lead (Brown et al., 2002; 2004). The high iron composts form bonds with the lead. Both lab tests and animal feeding studies have shown that these composts reduce the fraction of the lead that can be absorbed. In a feeding study mixing a high iron compost produced in Washington D.C. with soil from a Superfund site in Joplin, Missouri, lead availability was reduced by 25 percent in comparison to the un-

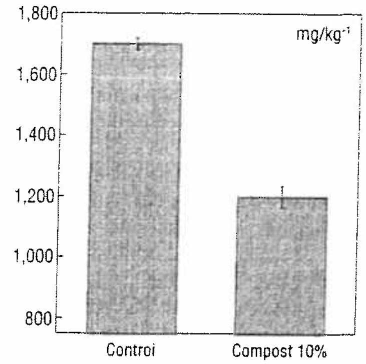
Table 1. Metal concentrations in two composts, and state pollutant limits

Metals	Cedar Grove Food & Yard	GroCo/ Biosolids	Washington Compost Limits
		(parts per million)	
Arsenic	6.6	2	20
Cadmium	1.6	1	10
Copper	45	136	750
Lead	37	19	150
Mercury	<1	0.38	8
Molybdenum	1.1	3	9
Nickel	21	8	210
Selenium	<1	2.3	18
Zinc	170	261	1400

treated soil. This reduction was in addition to the dilution effect mentioned earlier.

This means that for people living in an urban area who are concerned about the potential for high lead in their soil causing harm to children, an easy and effective solution is adding compost to their gardens. Composts will have low lead concentrations. They will be great for plants. Adding high rates of compost to soils will dilute soil lead and promote lush plant growth. Both make lead in the soil much less of a concern.

Figure 4. Change in total soil lead concentration after addition of 10% (by weight) biosolids compost



OTHER CONTAMINANTS

Urban soils also can contain elevated concentrations of contaminants other than lead. These include other metals as well as organic compounds. Plant uptake of organic chemicals is generally minimal (Luthy et al., 2002). This means that when considering the bioavailability of organic compounds, plant uptake is not a pathway of concern. In other words, concerns about organic contaminants in gardens should not be a consideration when growing food crops.

Knowing the history of industrial activities can be a clue to determining the likelihood of elevated contaminant concentrations. In Tacoma, Washington, for example, a metal smelter operating for many decades resulted in elevated lead and arsenic in city soils. Generally, if contamination is of sufficient magnitude to be concerned about, public health officials in a municipality will be cognizant of these contaminants.

For the urban gardener, potentially the most important consideration before starting a garden is the level of neglect suffered by the soils. Urban soils are nutrient poor, highly compacted and lacking in organic matter. All of these factors make growing a successful garden difficult. For all of these problems, adding high rates of compost will markedly improve your soils. In addition, using high rates of compost will reduce the concentration and potentially the bioavailability of any contaminants that may be in the soil. Compost will also bring you an excellent chance of a bountiful harvest. ■

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